Two-component processing and interpretation case history: Crystal East, central Alberta

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ABSTRACT

The Crystal East two-component survey was shot as two separate surveys into the same spread-layout, the vertical component survey and the radial component survey. Three lines were shot in total, using 1kg dynamite charges as sources.

The data processing sequence used in processing the seismic survey is outlined in this report, with particular emphasis on the processing of the radial component data. The processing sequence employed is the sequence presently in use for converted-wave surveys at the CREWES data processing center.

The ability of the seismic data to detect a Viking sandstone channel is examined using the final stacked seismic sections. Almost no evidence of an amplitude anomaly on the Viking reflector is present on either component of the three lines. However, using the ratio of P-wave traveltime to S-wave traveltime, or gamma-T ratio; derived from interval times on the radial and vertical component stack sections, serves to properly delineate the channel.

INTRODUCTION

Distinguishing shale from sandstone with similar P-wave velocity and density may not be possible using conventional P-wave recording. However, if it would be possible to obtain the S-wave velocity along with the P-wave velocity, then Poisson's ratio offers a method of distinguishing between such lithologies (Pickett, 1963; Garotta et. al., 1985, and others). By recording the radial (P-SV) component of wave motion along with the vertical (P-P) component it is possible to economically determine Poisson's ratio by correlating reflectors on the final stacked sections of the two components. This method is used on two-component data from the Crystal East field of central Alberta (Figure 1) in an attempt to distinguish between productive Viking sandstone conglomorate channels and adjacent shales. From previous experience as well as examination of sonic and density logs, it was observed that the Viking channels will not yield any noticable anomaly on conventional P-wave stacked sections. In order to test the applicability of using Poisson's ratio to differentiate between lithology, a two component survey was shot over the Viking channels. This paper details the processing and interpretation of the two component seismic data survey over a known Viking channel in the Crystal East field of central Alberta.

PROCESSING METHOD

The vertical and radial component of three two-component seismic lines of the Crystal East survey were processed for this study. The survey was recorded using 1 kg

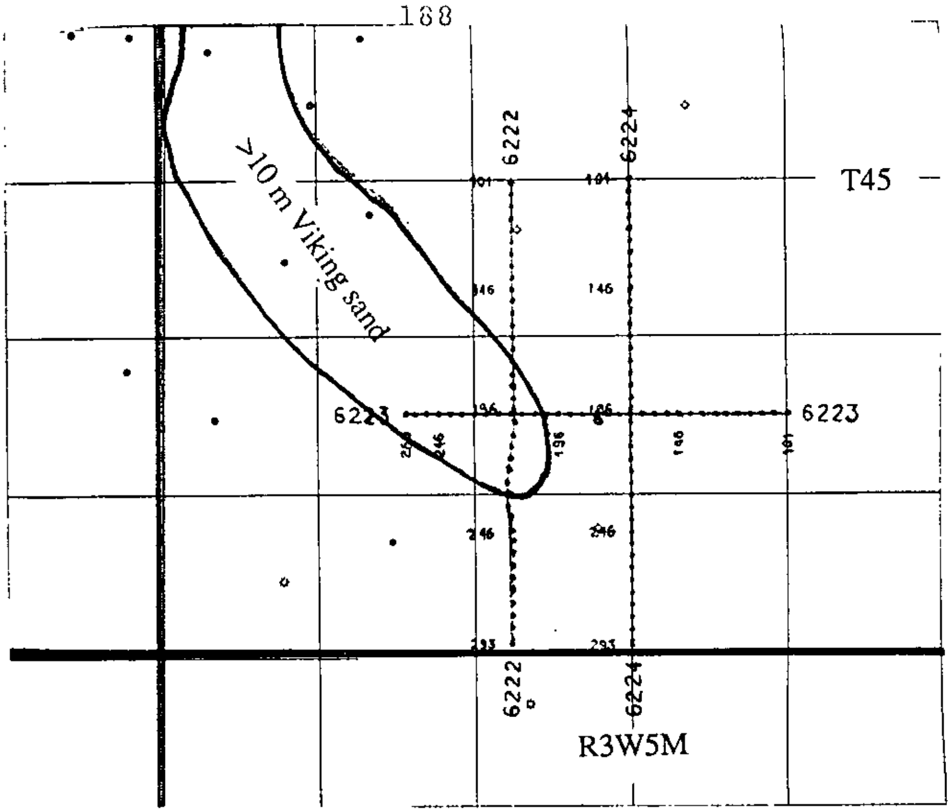


Fig. 1: Location of lines 6222, 6223 and 6224 of the Crystal East two-component seismic survey, central Alberta.

dynamite charges as sources and a 120-trace recording system. The radial component was recorded as a separate survey, using a different geophone type, geophone array and spread layout than the vertical component survey. The field acquisition parameters are summarized in Table 1.

Energy source	Dynamite
Charge size	1 kg
Hole Depth	18 m
Geophone array	Radial: 9 over 75 m Vertical: 9 over 25 m
Geophone type	Radial: LRS 280, 8.5 Hz Vertical: LRS 280, 14 Hz
Groups recorded	120
Group interval	25 m
Normal source interval	50 m
Near offset	Radial: 62.5 m Vertical: 37.5
Recorder type	DFS V
Number of channels	120
Sample rate	2 ms
Low cut filter	Out
Antialias filter	120 Hz
60 Hz notch filter	In
Fixed gain	36 db

Table 1: Acquisition parameters for Crystal East survey

Shot records at the same location for the two directions of recorded motion, the vertical component and the radial component are shown in Figure 2. Individual trace balancing as well as a time-variant gain function are applied to the field records in order to correct to geometrical spreading and field gain. Since the Vp/Vs ratios for most lithologies likely to be encountered in this area are about 2.0 (see Tathar, 1985 and Harrison, 1989), all radial component data presented are plotted at two-thirds the vertical scale of the vertical component data. This allows for easy visual correlation between the two data sets.

The vertical component data clearly shows the presence of a noisetrain with a velocity of about 610 m/s. This noisetrain is also present of the radial component data, which is further evidence that this noisetrain is the Rayleigh wave propagating along the ground surface, or otherwise known as ground roll (Akai and Richards, 1980).

The radial component data also indicates the presence of another noisetrain, with a velocity of about 1160 m/s. From its velocity and lack of presence on the vertical component, this is assumed to be a source-generated, shear refraction (Schafer, 1990). Since the P-wave refractions have a velocity of 3030 m/s, the Vp/Vs ratio of the near surface would be 2.61 using the shear refractions, which is reasonable for the unconsolidated sediments of the near surface (Garotta, 1985).

In general, the radial component record contains a fair signal strength, although a lot of the signal is covered by the noisetrains. The indication of events correlating with the vertical component is apparent on the right hand side of the radial component record at about 2.0 s two-way travel time, as well as in the shallow record, above 1.4 s.

Processing of the vertical channel follows the standard P-wave processing flow outlined in Table 2, since the vertical channel is exactly that recorded in conventional P-wave surveys.

DEMULTIPLEX
GEOMETRIC SPREADING COMPENSATION
SPIKING DECONVOLUTION
    100 ms operator, 0.1% prewhitening
CDP SORT
APPLY ELEVATION & REFRACTION STATICS
INITIAL VELOCITY ANALYSIS
AUTOMATIC SURFACE-CONSISTENT STATICS
    Correlation window of 800 to 1900 ms
    Maximum shift of + or -24 ms
VELOCITY ANALYSIS
NORMAL MOVEOUT APPLICATION
MUTE
CDP TRIM STATICS
    Correlation window from 400 to 1900 ms
    Maximum shift of + or -12 ms
STACK
BANDPASS FILTER
    Zero-phase, 12-65 Hz
RMS GAIN
    First window of 200 ms, second of 400 ms,
    subsequent windows of 400 ms length.
F-K FILTER
    Pass-band from -2 to +2 ms/trace

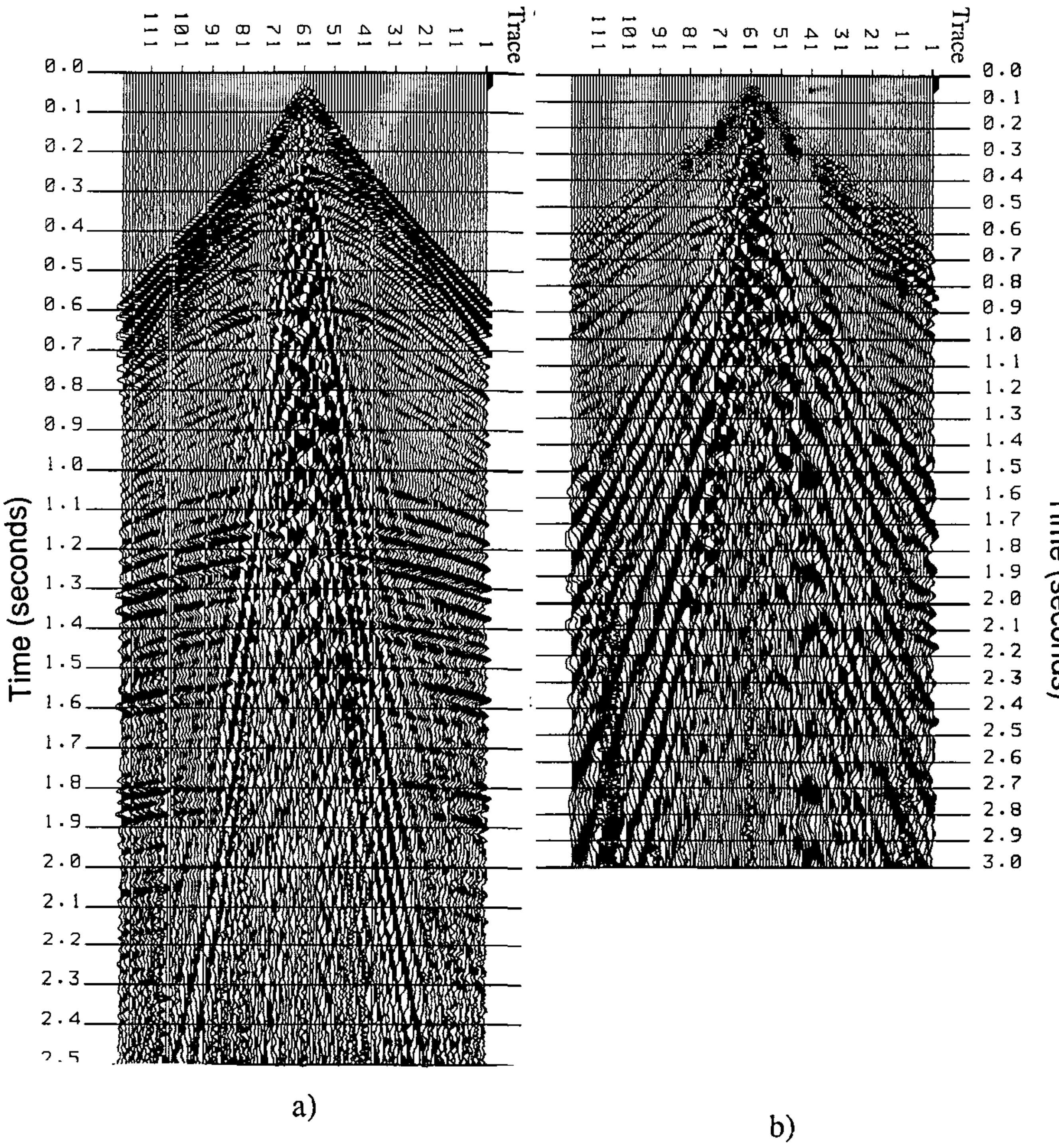


Fig 2: Sample shot record from a) the vertical (P-P) component and b) the radial (P-SV) component data sets from line 6223, Crystal East, central Alberta

6 db maximum reject.

Table 2: Processing sequence and parameters for the vertical (P-P) component data.

Processing of the radial component requires several modifications due to the differences associated with P-wave and S-wave motion. The radial component records converted waves, which travel from the source to the receiver as P-waves, then convert to S-waves upon reflection from an interface, and travel from the interface to the receivers as S-waves. The most noticable differences lie in the shift of the CRP from the midpoint towards the receiver (Slotboom and Lawton, 1989), and increased receiver statics (Schafer, 1990). The processing flow used, modelled after Harrison, 1989, is shown in Table 3.

DEMULTIPLEX
GEOMETRIC SPREADING COMPENSATION
SPIKING DECONVOLUTION
    120 ms operator, 0.1% prewhitening
REVERSE THE POLARITY OF TRAILING SPREAD
APPLY FINAL P-WAVE STATICS
INITIAL VELOCITY ANALYSIS
APPLY HAND STATICS FROM SURFACE STACKS
AUTOMATIC SURFACE-CONSISTENT STATICS
    Correlation window from 400 to 2200 ms
    Maximum shift of + or -24 ms
CDP STACK
CONVERTED WAVE REBINNING
    Vp/Vs of 1.96 used
VELOCITY ANALYSIS
NORMAL MOVEOUT APPLICATION
MUTE
STACK
BANDPASS FILTER
    Zero-phase, 8-35 hz
RMS GAIN
    First window of 200 ms, second of 400 ms,
    subsequent windows of 400 ms length
F-K FILTER
    Pass-band from -3 to +3 ms/trace
    6 db maximum reject.

Table 3: Processing sequence and parameters for the radial (P-SV) component data.

Sample velocity analysis plots for the vertical and radial channels show the stacking velocities used for the final stacked section (Figure 3). NMO-corrected common-offset stack records are generated to design a mute function and demonstrate the changes in amplitude and phase with offset (Figure 4). In order to display the frequencies of the final stacked section a cross power spectrum between two adjacent traces is genertated (Figure 5). The usable frequency bandwidth for the vertical channel is seen to be from about 10 to 60 Hz, while the bandwidth for the radial channel is from 8 to 35 Hz. Receiver static correction for the converted-wave case had to be picked by hand from a common-receiver

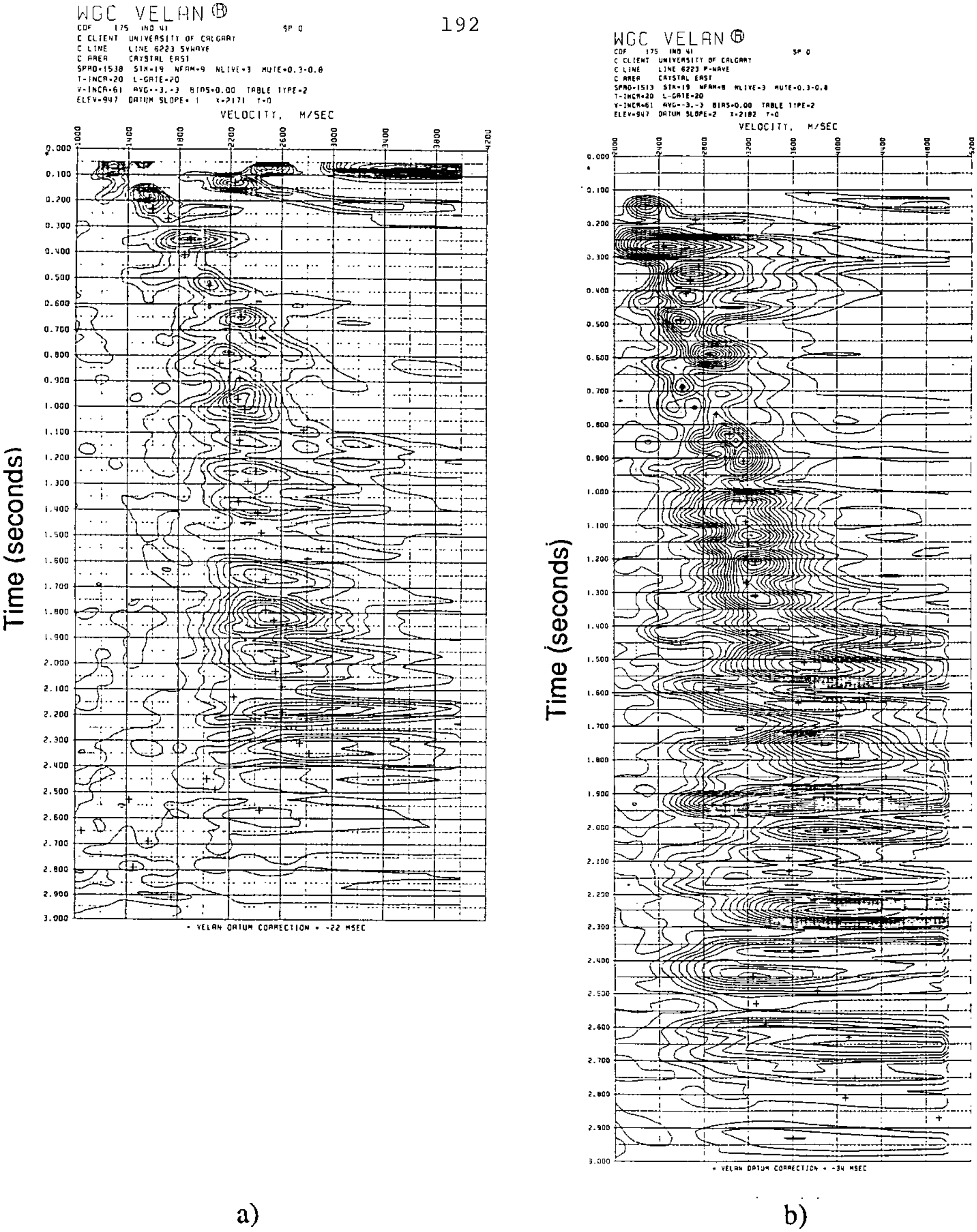


Fig 3: Sample velocity analysis plots for a) the radial (P-SV) component and b) the vertical (P-P) component data sets from line 6223, Crystal East, central Alberta.

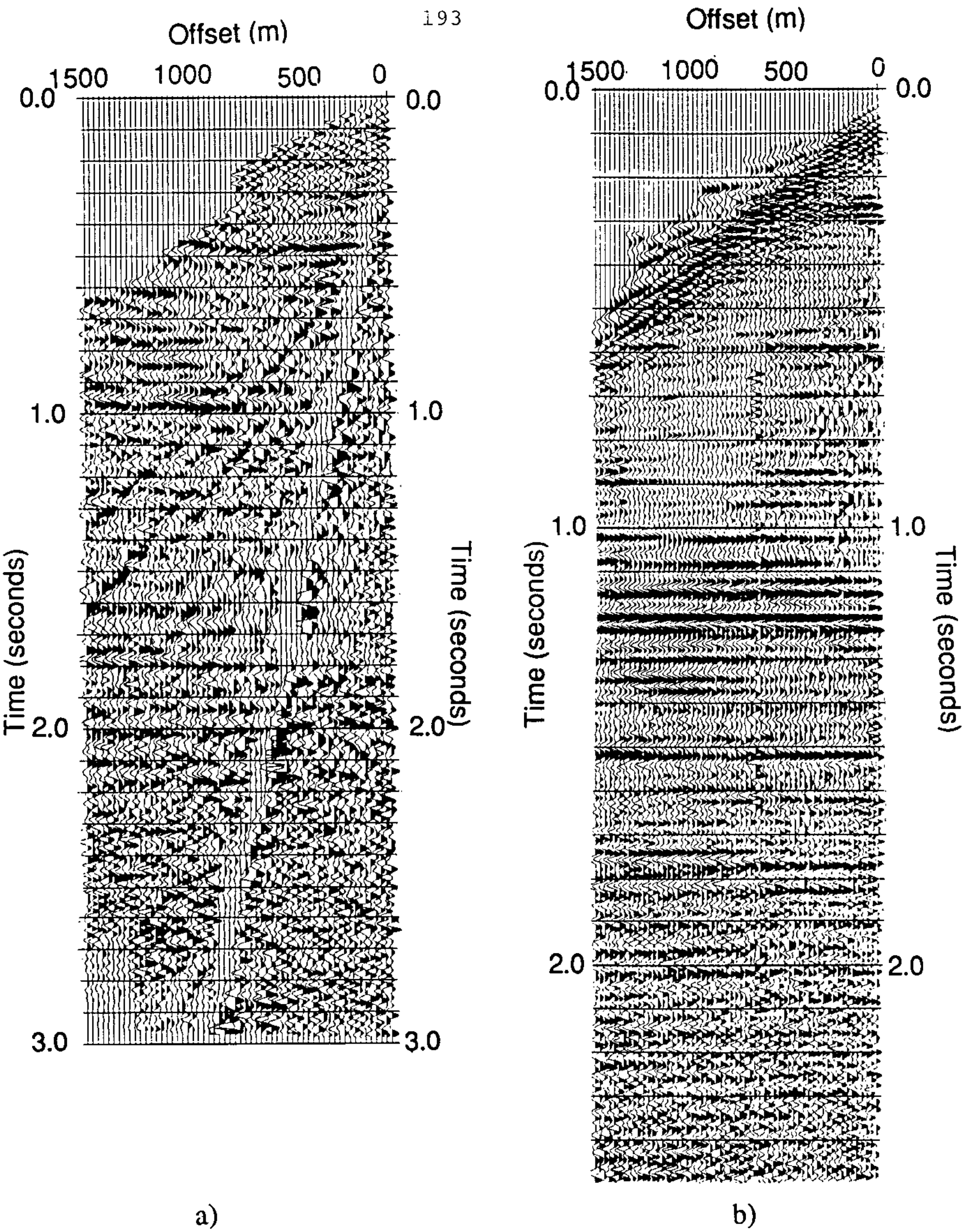
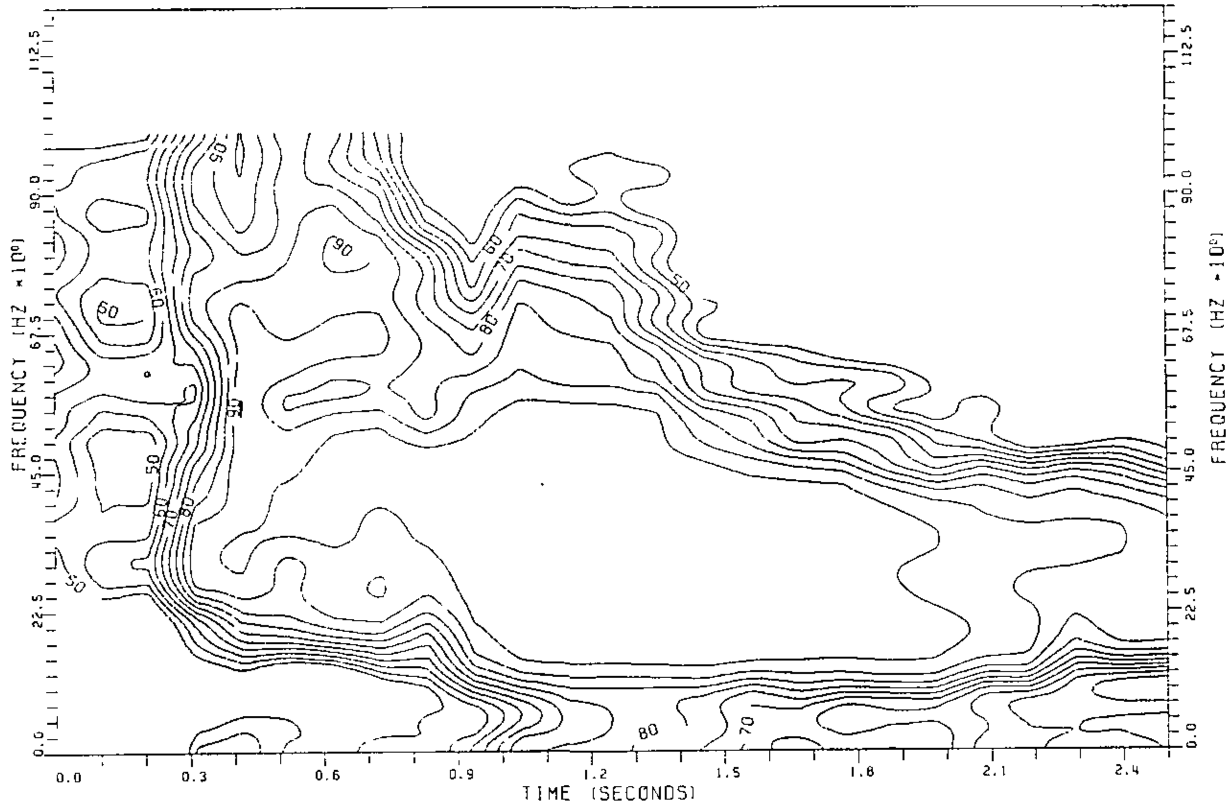
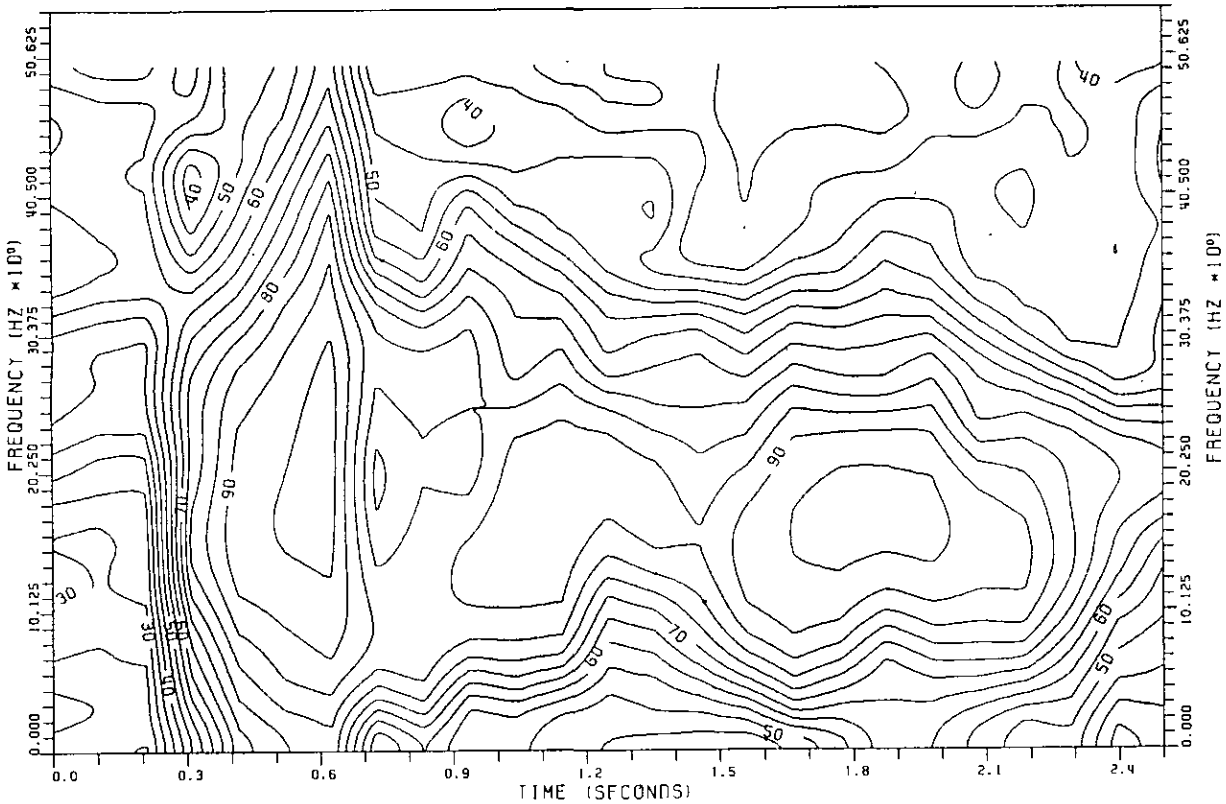


Fig 4: Sample NMO-corrected common-offset stack records for a) the radial (P-SV) component and b) the vertical (P-P) component data sets from line 6223, Crystal East, central Alberta.



a)



b)

Fig 5: Average time-variant cross-power spectrum between adacent stack traces for a) the vertical (P-P) component and b) the radial (P-SV) component data sets.

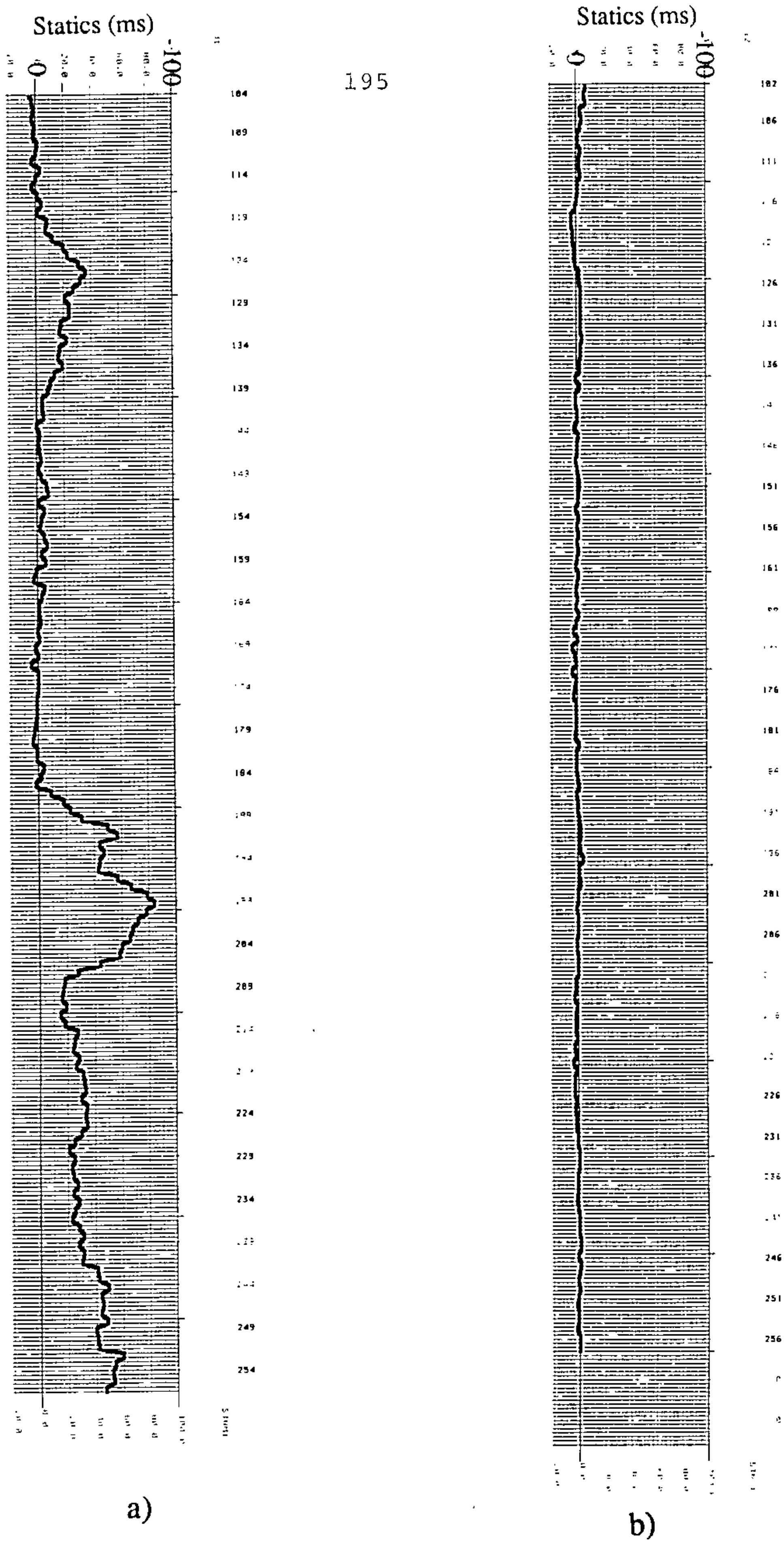


Fig 6: Final CDP statics for a) the radial (P-SV) component and b) the vertical (P-P) component data sets.

stacked section, since the P-wave static solution was adequate for the sources, but had little effect on the large high-frequency static shifts seen on the receivers. The final static solution applied to the vertical and radial component data is shown as Figure 6.

The final stack section for the three lines in the Crystal East survey are shown as Figures 7, 8 and 9. These section have the final statics solution applied, as well as a mild f-k filter with a pass-band from -2 to +2 ms/trace for the vertical component and -3 to +3 ms/trace for the radial component data sets, with a 6 db maximum reject. The correlation between the P-wave section and the converted-wave section can be readilymade by examination of the character of a part of the P-wave section and its continuation as a converted-wave section (Figure 10).

Using the correlated event times, time intervals are calculated for the P-P and the P-SV case to give a ratio of P-wave velocity to S-wave velocity, Vp/Vs, using the following formula:

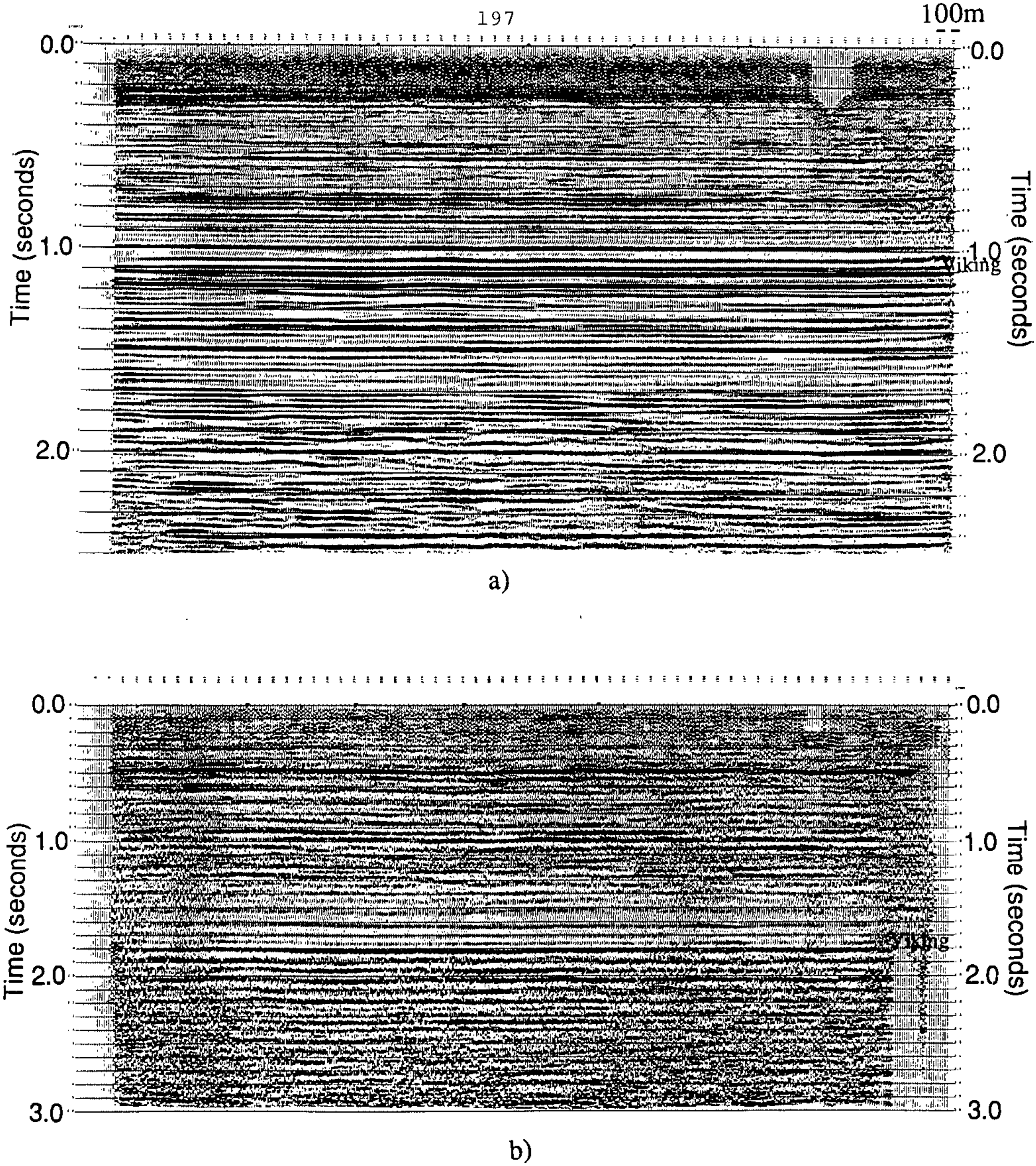
$$V_p/V_s = \frac{2I_s}{I_p} - 1$$

where I_p is the P-P time interval, and I_s is the P-SV time interval.

The results are given in Table 4.

P-P time	P-P interval	P-SV time	P-SV interval	Vp/Vs
130 ms		310 ms		
	105 ms		170 ms	2.24
235 ms		498 ms		
	322 ms		498 ms	2.09
557 ms		978 ms		
	298 ms		462 ms	2.10
855 ms		1440 ms		
	135 ms		175 ms	1.59
990 ms		1615 ms		
	60 ms		85 ms	1.83
1051 ms		1700 ms		
	37 ms		50 ms	1.70
1088 ms	** VIKING **	1750 ms		
	32 ms		50 ms	2.13
1120 ms		1800 ms		
	150 ms		210 ms	1.84
1270 ms		2010 ms		
	220 ms		310 ms	1.82
1490 ms		2320 ms		

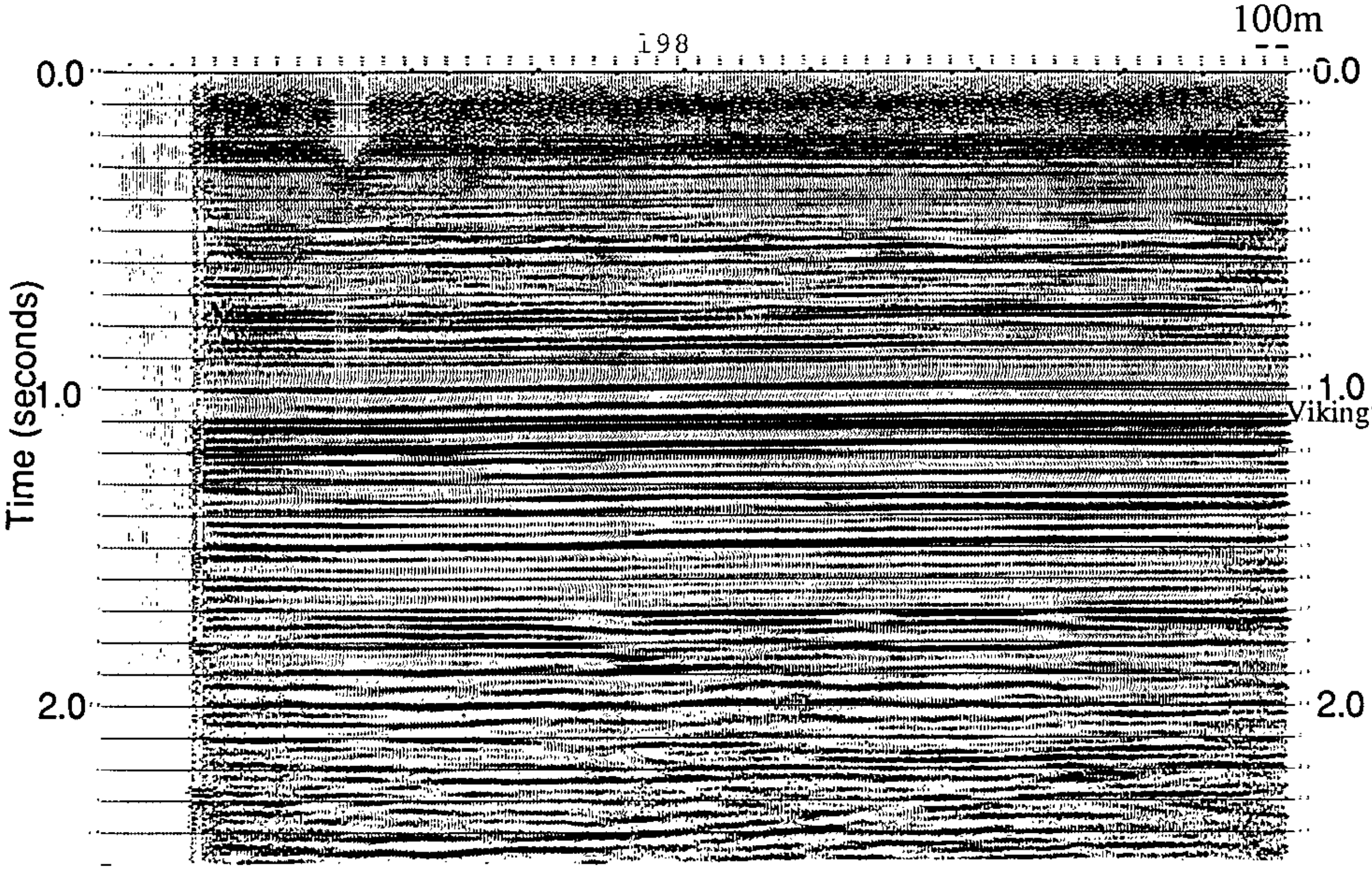
Table 4: Vp/Vs ratios computed from event and interval time for reflected (P-P) and converted (P-SV) data.



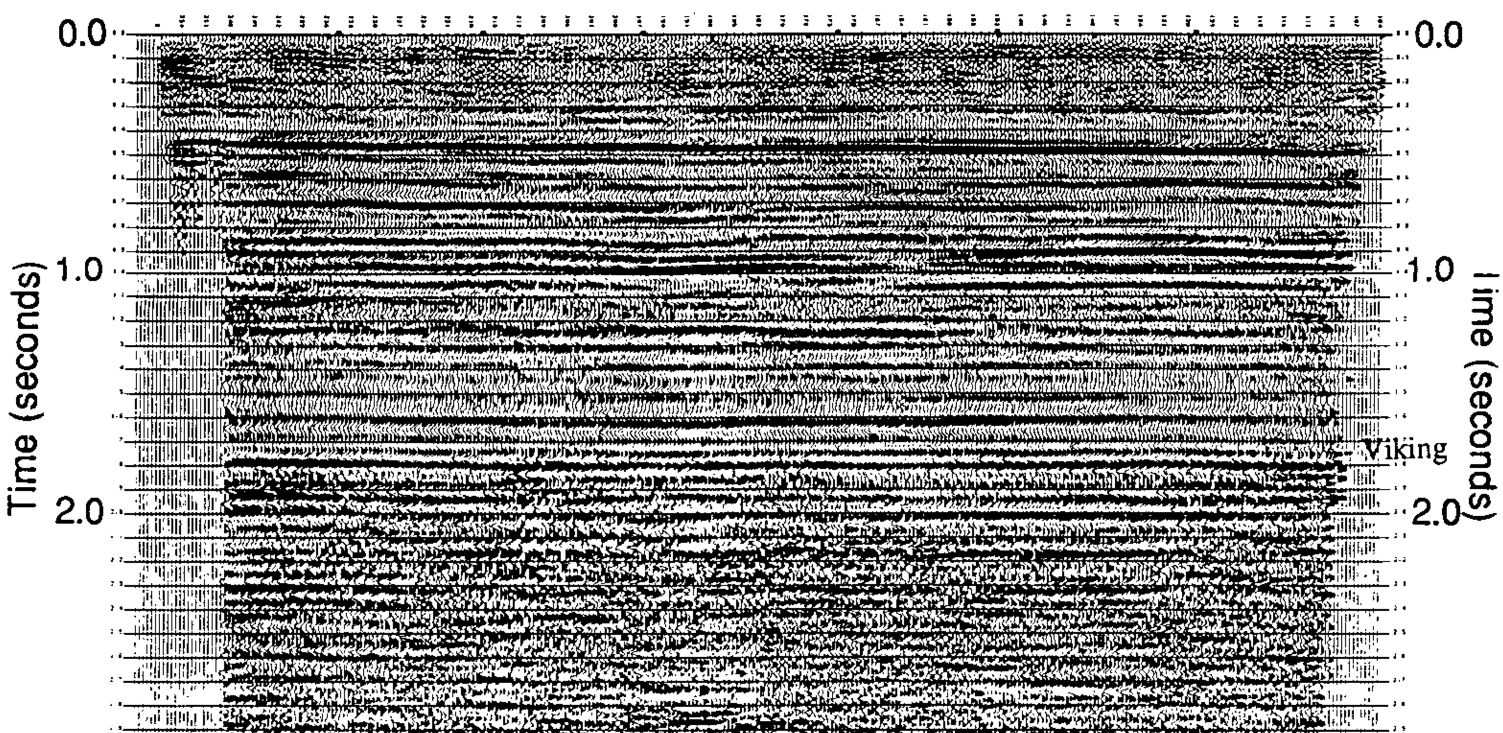
a)

b)

Fig 7: Final stack section for a) the vertical (P-P) component and b) the radial (P-SV) component data sets from line 6222, Crystal East, central Alberta.



a)



b)

Fig 8: Final stack section for a) the vertical (P-P) component and b) the radial (P-SV) component data sets from line 6223, Crystal East, central Alberta.

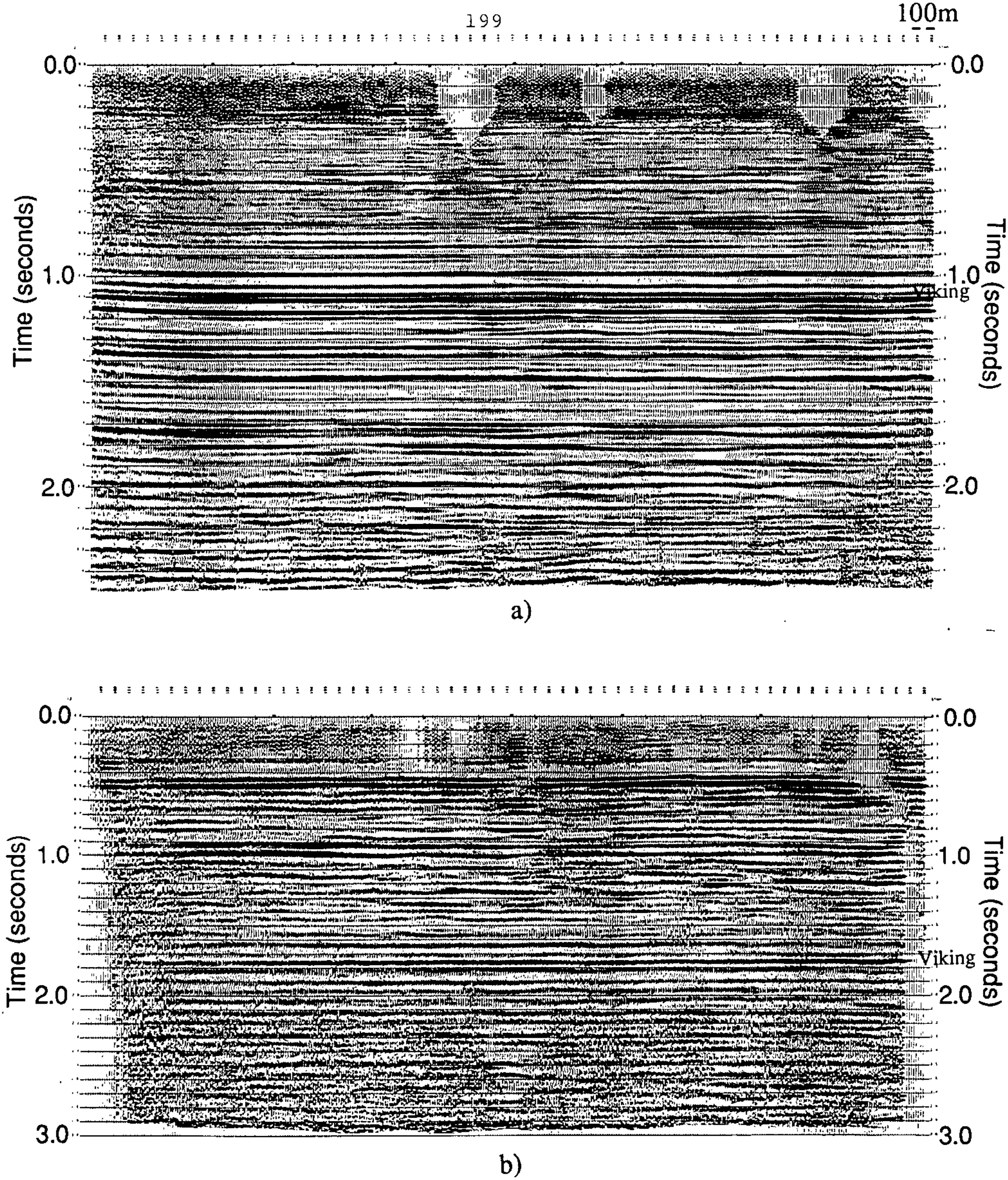


Fig 9: Final stack section for a) the vertical (P-P) component and b) the radial (P-SV) component data sets from line 6224, Crystal East, central Alberta.

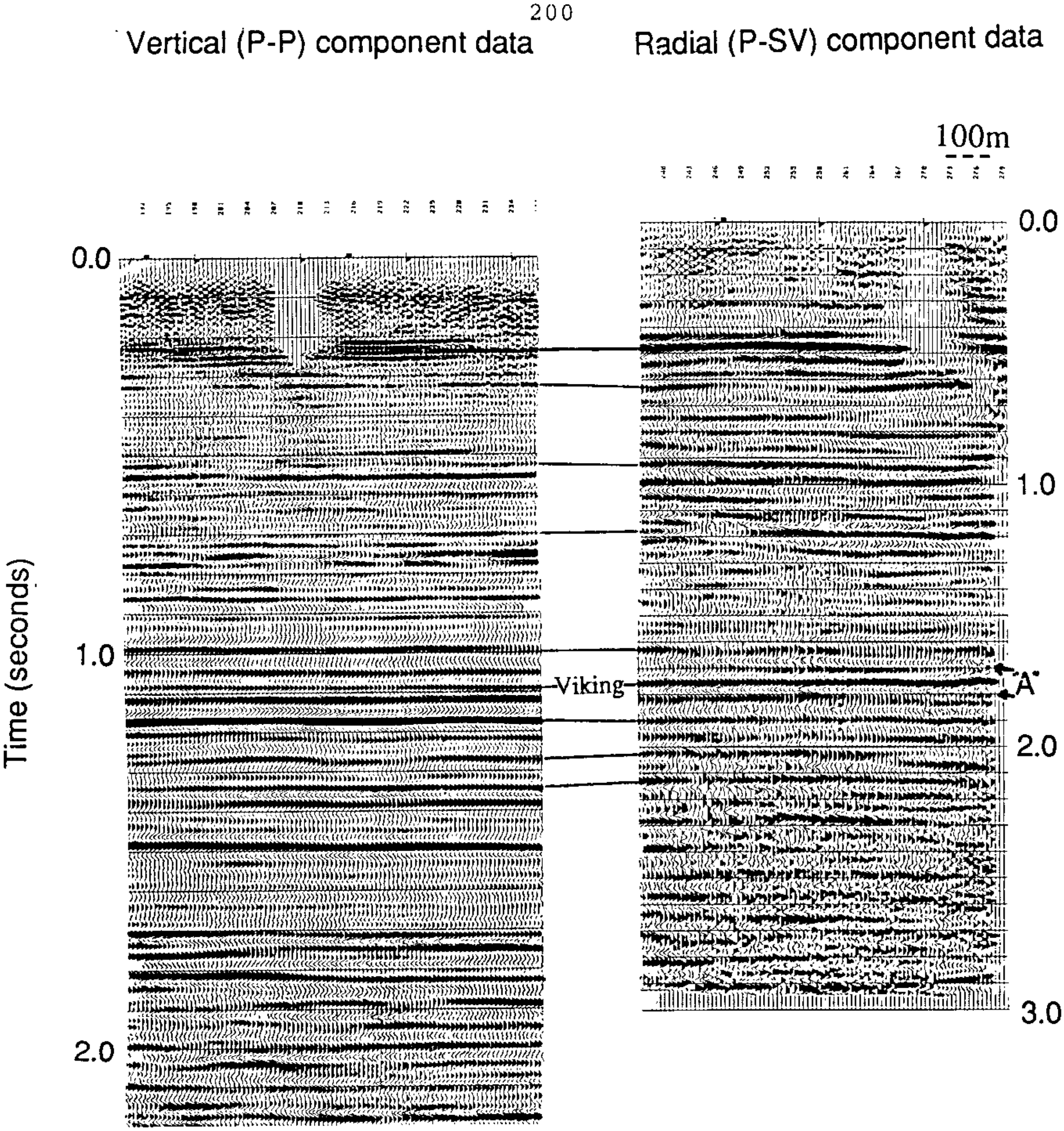


Fig 10: Correlation between P-P and P-SV events on the final stack sections from line 6224, Crystal East, central Alberta.

A time weighted average over the whole section is then used to properly rebin the converted-wave data (see Harrison, 1989).

INTERPRETATION

The targets in the Crystal East field are Viking sand channels. The play is stratigraphic, with sand channels interbedded in the surrounding shale. Deposition of these sands is most likely due to the high energy environment of storm events (Beach, 1962 and Koldijk, 1976). Since the sand channels have a similar P-wave velocity as the surrounding shales, conventional zero-offset P-wave seismic sections will not show an anomaly over the channel. However, from previous studies over similar channels, it was shown that using the ratio of P-wave travel time to S-wave travel time can be useful for discriminating sandstone from shale (Garotta, 1985). This is due to the change observed in the S-wave velocity, even when the P-wave velocties are similar for both lithologies. The ratio of P-wave to S-wave traveltime through a specific interval has been named the 'gamma-T' ratio, and when plotted versus Poisson's ratio, clearly demonstrates the differentiation between sandstone and shale (Figure 11).

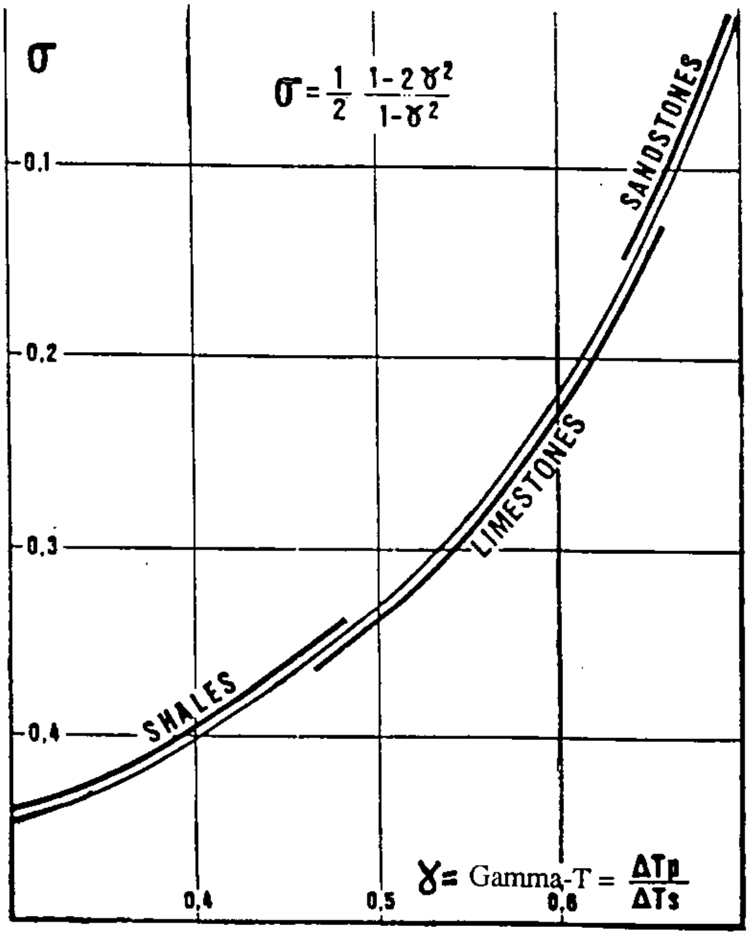


Fig. 11: Relation between Poisson's ratio and the gamma-T coefficient (Garotta et. al., 1985).

The extent of the Viking sand channel in the Crystal East survey is roughly outlined by the 10 m sand thickness isopach, shown in Figure 1. Examination of the three lines fails to indicate an increase in amplitude of the Viking reflection on either the vertical or Radial components (Figures 8, 9 and 10). Thus, in the hope that an analysis of the gamma-T ratio over the Viking zone will be able to discern what the naked eye can not, gamma-T ratios were calculated for the interval 'A'. (Figure 10). The interval chosen for this analysis extends from a reflector just above the top of the Viking to another reflector just below the Viking, since attempting to pick only the actual Viking zone would require instantaneous phase displays. Due to the variations in fold and offsets in the sections, wave form variations would occur which will introduce error into the analysis. Choosing a larger interval allows for the wave form variations to be reduced, however also reduces the magnitude of the anomaly expected from the Viking channel. Further, variations in lithology inside the range chosen may also serve to interfer with the observed anomaly. The results of this analysis on line 6223 are shown as Figure 12. The results of this analysis for line 6223 of the Crystal East survey, along with the geological model of the sand channel, are shown in Figure 12.

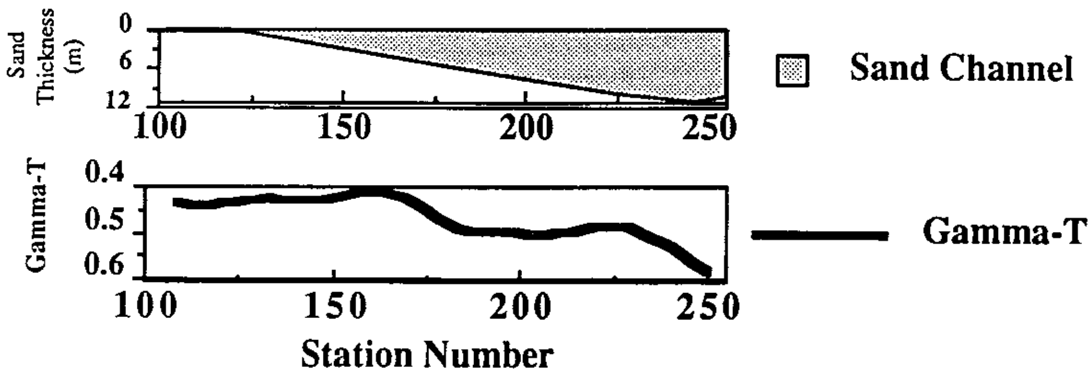


Figure 12: Viking sand channel model and corresponding gamma-T anomaly for line 6223 of the Crystal East survey.

DISCUSSION

The processing of a 2-component survey requires considerably more time and effort than a conventional P-wave survey would. Receiver statics on the radial component data must be hand-picked, ofter requiring several attempts before a satisfactory solution is obtained. Then, after initial final stack sections are completed for both the vertical and radial components, Vp/Vs ratios must be calculated and an average Vp/Vs ratio is used to rebin the radial component data to arrive at the final stack section for the radial component.

Processing of the radial component is also made more difficult by the presence of more noise than on the vertical component records, such as the shear refraction and a general increase in random noise.

Finally, in order to properly process the converted-wave data on the radial component records, many of the programs used must be modified from the P-wave case. For example, the data must be rebinned according to the CRP, rather than the CMP, and many other programs, such as NMO correction require modifications in order to be properly applied to the P-SV case (Slotboom et. al., 1990).

However, despite all of the difficulties involved in processing the data, reasonable stacked sections were obtained from the radial component data. The advantage of having a converted-wave section becomes apparent in the ability to derive another physical property of rocks, the S-wave velocity. Using the ratio of the P-wave to S-wave velocity, the gamma-T ratio, allows differentiation of Viking sandstone channels from the background shale. The gamma-T plots clearly shows lower values over the channel zone than the background values of about 0.44, with the magnitude of the anomaly corresponding well with the sand thickness.

CONCLUSIONS

Processing of the radial component data requires several modification to the regular P-wave processing sequence used on the vertical component data. Initial rebinning to CRP's (Tessler and Behle, 1988, and Slotboom and Lawton, 1990), picking hand statics for the receiver statics, and a second rebinning using the average Vp/Vs ratio are some of the major differences.

The final radial component stack sections contain fairly good signal strength and correlate well with the vertical component stack sections.

There are no obvious increases in the amplitude of the Viking reflections over a known Viking sandstone channel on either the vertical or radial component stack sections.

The Viking sandstone channel can be delineated by using an analysis of the gamma-T ratio on the two separate component stack sections.

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